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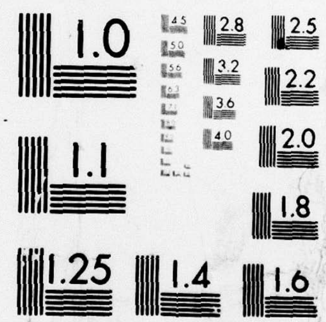

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COMPARATIVE INTELLIGIBILITY OF STANDARDIZED TEST MATERIALS PROCESSED BY THE ARC-164 AND ARC-34 RADIO SYSTEMS IN THE PRESENCE OF SIMULATED COCKPIT NOISE

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DECEMBER 1979

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

Henning E. von Gierke

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Director
Biodynamics and Bioengineering Division
Air Force Aerospace Medical Research Laboratory

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A laboratory evaluation was conducted of the comparative intelligibility of standardized speech materials (MRT) processed through representative Air Force communication systems in the presence of various levels of aircraft cockpit noise. The results indicated that as the level of noise was increased the intelligibility of the speech materials was systematically decreased. Although both radio systems tested were affected, the relative magnitude of the effect varied for the two systems from one noise level to the other.

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INTRODUCTION

A major requirement of a voice communication system is the ability to make a reasonable prediction of the intelligibility of speech signals processed through the system. An attempt will often be made to satisfy this requirement by calculating the Articulation Index (Acoustical Society of America, 1970; French and Steinberg, 1947). However, the Articulation Index does not always serve as a reliable predictor of field intelligibility of the developed system when the need is to evaluate systems utilizing complex speech processing algorithms (e.g. digital radio systems). Due to this, empirical intelligibility testing under laboratory conditions employing listener panels is utilized. These laboratory evaluations often evaluate the system being tested under relatively "ideal" conditions. It would be more advantageous to conduct laboratory intelligibility testing of voice communication systems with the systems and the listeners in as near an operational configuration as possible. For example, in evaluating an Air Force radio system, the radio's input should be processed through a standard aircraft intercommunications system, all listeners and speakers should wear standard custom fitted AF helmets, earphones and oxygen masks, through which they breathe compressed air and which contain a standard microphone. Likewise, the noise environment in which the systems are to be eventually used should be modeled as closely as possible. This is true not only for the listener, in order to evaluate possible masking effects on intelligibility, but also for the speaker, since ambient noise conditions will often cause the speaker to modify his vocal effort, thereby altering the acoustic content of his speech. The present study has a two-fold purpose, first the evaluation of the effect of different levels of a simulated operational noise on the intelligibility of standardized speech materials as processed through representative AF radio systems and second the gathering of base-line performance data on the ARC-164

radio system. The ARC-164 will serve as the reference system against which the performance of systems developed in the immediate future under such programs as SEEK TALK will be compared.

METHOD

Approach

The comparative intelligibility of standardized test materials processed through representative Air Force communication systems was measured in the presence of varying levels of simulated operational noise. Volunteer listeners wearing standard inflight helmets responded to the communication signals under the specified experimental conditions. Decrements in comparative intelligibility were attributed to level of simulated operational noise employed.

Subjects

Ten subjects, five male and five female, were employed in the present studies. All were recruited from the general civilian population. They were paid at an hourly rate for their participation, with a cash bonus awarded when the subject completed all sessions. The hearing levels of all subjects were no greater than 15 dB at any standard audiometric test frequency from 500 to 6000 Hz.

Facilities

These studies employed the Voice Communication Research and Evaluation System (VOCRES) of the Aerospace Medical Research Laboratory (McKinley, 1979). This system has the capability to realistically model the major acoustic factors experienced by crew members that may adversely affect voice communications.

The overall system includes a master control station and ten individual aircraft communication stations. Each station contains the Air Force standard intercommunication system (AIC-25) and respiration system (A-19 Oxygen Regulators). Both intercommunication and respiration terminals and operating

controls are easily accessible to the individual positioned at the station. Each station is also integrated into a Computer-Display-Response system in which the central processor is a Hewlett-Packard 9845A System. An interface at each station decodes commands by the central processor for the station's display and also returns the subject's response to the central processor for storage and analysis.

For these studies all volunteers wore the standard Air Force Flight Helmet, HGU-26/P with the H-154A earcup assembly. Helmets were individually fitted to each subject by personnel of the AMRL Human Engineering Division. Either the MBU-5/P or MBU-12/P AF standard oxygen mask with the M-101 noise cancelling microphone was worn by each volunteer. Previous testing has found these two masks to be equivalent in performance. Compressed air was respired through A-19 Diluter Demand Pressure Breathing Regulators set at normal operation by all subjects during the talking and listening phases of the studies.

The acoustic environment simulation facility consists of a large reverberation chamber (approximately 3000 ft^3) that houses a powerful electrodynamic sound system. The electrodynamic system contains dual amplifiers that may be used singly or in combination. One system (low power) consists of two 600- watt amplifiers and the other (high power) consists of two 7000-watt amplifiers. The amplifiers drive 32 loudspeaker enclosures, each containing three 15-inch loudspeakers and twelve 3-inch high frequency "tweeters." The loudspeaker enclosures are portable and may be rearranged for various purposes. In the configuration used for these studies, the low power system generates a maximum overall Sound Pressure Level (SPL) of 122 dB, while the high power system generates a maximum overall SPL of 128 dB re 20μPa (with a pink noise input).

The low power system was used in the cockpit noise environment simulation. A pink noise source was shaped by a 1/3 octave band spectrum shaper (or filter bank) so that the spectrum measured in the test space was representative of that produced by a typical jet fighter aircraft.

The transmitters and receivers were either ARC-164 or ARC-34 radios. Both are current operational Air Force aircraft radios. The communication signals were processed by the radios and then presented to the listeners through the standard Air Force aircraft intercommunication system and terminal equipment.

All connections between the RF transmitter and receiver were made by means of standard 50 ohm coaxial cable.

Measurement Instrument

This study employed a standardized measure of intelligibility, the Modified Rhyme Test (MRT) as developed by House, et al (1963) for assessing communication effectiveness. The MRT was selected for use over other test materials because of evidence that it is the test of choice for evaluating the performance of military speech communication systems in the presence of environmental noise (Webster and Allen, 1972). The materials consist of lists of 50 one-syllable words that are equivalent (lists) in intelligibility. These test words are presented embedded within a carrier phase that is the same for each item. The MRT is easy to administer, score and evaluate and it does not require extensive training of listeners. The display at the talker's station (Fig 1) provided the text which the talker read, the listeners' stations (Fig 2) provided a choice of six key words from which the listener selected the one he/she felt was correct by pressing the button beside it. To compensate for correct answers obtained by guessing a correction factor was applied to the scores.

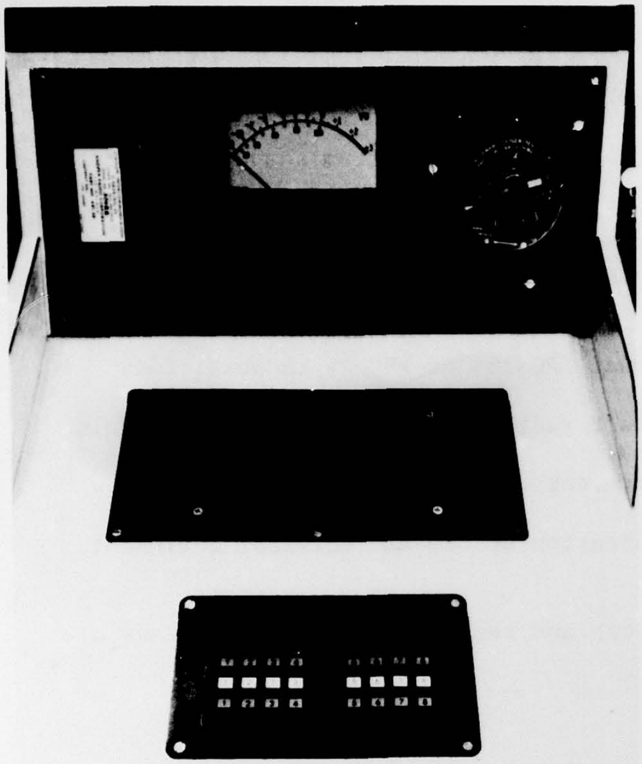

Figure 1 (left)

DISPLAY AT THE TALKER'S STATION

Text displayed is representative of used in the present study, consisting of a carrier phrase and the key word.

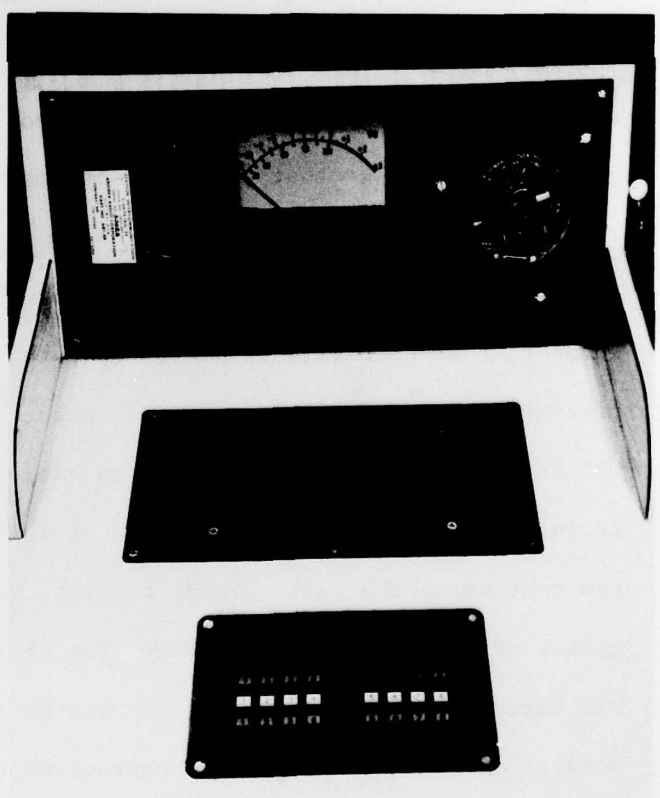

Figure 2 (right)

DISPLAY AT THE LISTENER'S STATION

Six response choices are given. The listener presses the button opposite the one he or she thinks is correct.

Experimental Procedure

The present study was designed so that each subject served as his/her own control, i.e., each subject participated in all experimental conditions. Order of presentation of experimental conditions was randomized, with the exception that evaluations were completed on the ARC-34 before they were started on the ARC-164. Data was not gathered for the ARC-34 under ambient noise conditions in the test chamber, while it was for the ARC-164.

Five of the ten subjects, three male and two female, were selected to serve as talkers. These individuals served as talkers and listeners in a "round-robin" fashion. The talker on any one trial served as a listener on previous and subsequent trials. Subjects participated for 4 hours per day in experimental sessions of about 40 minutes followed by 15 minute rest periods. All ten subjects were run simultaneously within the VOCRES facility. A block diagram of the experimental setup is shown in Figure 3. The helmets and earphones worn by the subjects provided about 20 dB attenuation of the environmental noise.

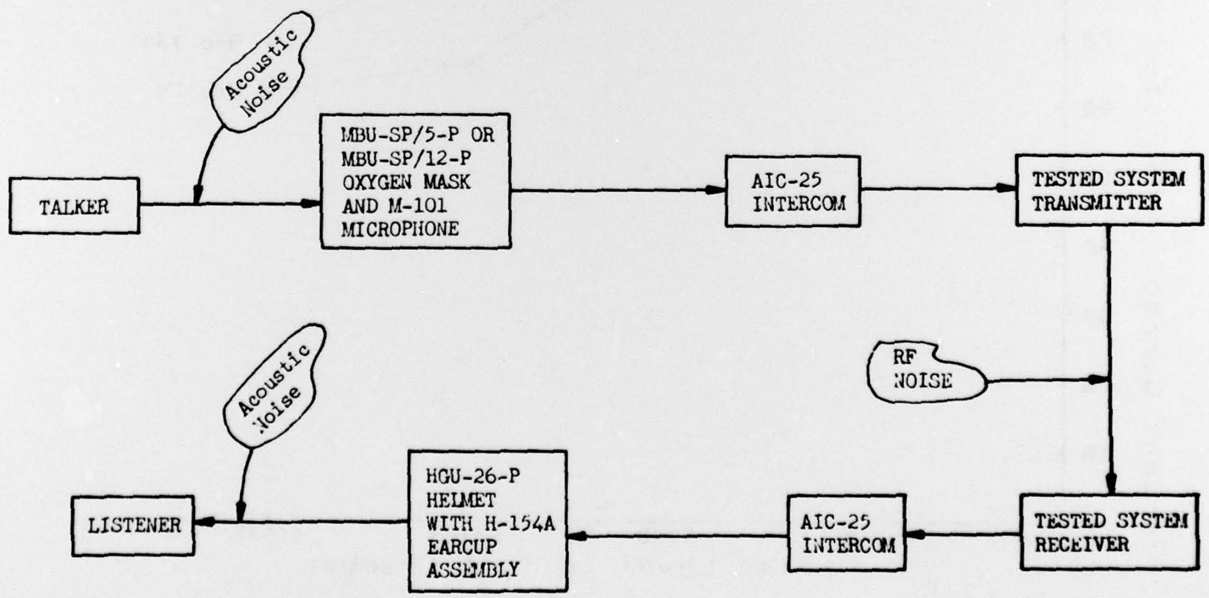

Figure 3. Block diagram of experimental equipment

RESULTS

Figure 4 summarizes the results from this study. Percent correct intelligibility (adjusted for chance) for MRT words processed through the ARC-164 or the ARC-34 radio systems is shown as a function of the level of a simulated operational noise environment. Data was also taken for the ARC-164 radio in the absence of a simulated operational noise, i.e., in the ambient noise level of the test chamber. This ambient level is approximately 75 dB. As can be seen from Fig. 4, increasing the level of the simulated operational noise results in dramatic decrements in percent intelligibility for both radio systems. For the ARC-164 percent correct decreases from 93 in the ambient noise condition to 71 in the presence of a 115 dB simulated operational noise. For the ARC 34 an increase

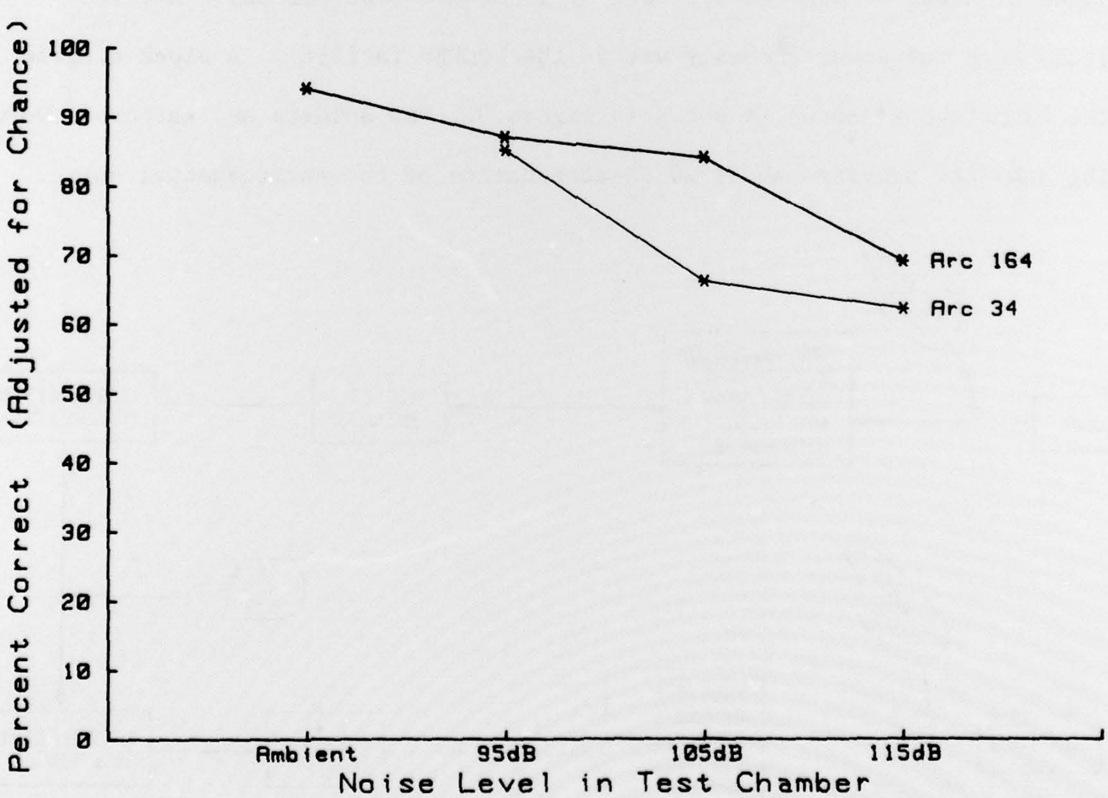

Figure 4. Percent correct responses (adjusted for chance) for the ARC-164 and ARC-34 radio systems tested in various levels of simulated cockpit noise. The measurement instrument was the Modified Rhyme Test.

in level of the simulated operational noise from 95 dB to 115 dB resulted in a decrease in the percent correct from 86 to 63. Not only does increasing the noise level systematically affect the percent correct, but also its effect differs across the two radio systems. While there is only two percent correct difference between the ARC 164 and the ARC 34 in the presence of a 95 dB simulated operational noise, the difference is about 20 percent at 105 dB and 8 percent at 115 dB.

DISCUSSION

The present study attempted to evaluate the effects of different levels of operational noise on the intelligibility of standardized speech materials as processed through representative radio systems. The results indicated that as the level of noise was increased the intelligibility of the speech materials was systematically decreased. However, although both radio systems tested were affected, the relative magnitude of the effect varied for the two systems from one noise level to the other. The greatest decrease in intelligibility occurred for the ARC 34 when the noise level was increased from 95 dB to 105 dB, with a slight additional decrease at 115 dB. The ARC 164 decreased only slightly in intelligibility from 95 dB to 105 dB and suffered a dramatic decrement in intelligibility when the noise level was increased to 115 dB. This is probably due to the different band width of the two radios. The ARC 34 has 4 times the band width and therefore accepts more random noise power at the receiver. Further, the frequency accuracy of the ARC-34 is not nearly as good as the ARC 164. These two phenomena result in speech processed by the ARC 34 being masked to a greater extent and at a lower noise level than speech transmitted and received by ARC 164.

These results support the contention that laboratory intelligibility testing of noise communication systems should be conducted with the systems and the listening panel in as near an operational configuration as possible. The level of environmental noise that the talkers and listeners will be operating in should be considered an important variable. Not only does it affect the results for speech processed through a particular voice communication system, but the effects may differ from one system to another.

CONCLUSION

A laboratory evaluation has been conducted of the comparative intelligibility of standardized speech materials (MRT) processed through representative Air Force voice communication systems in the presence of various levels of aircraft cockpit noise. Word intelligibility was degraded by the presence of the simulated cockpit noise for both systems tested and the effects were not the same for both systems.

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